A New METHOD For Discovering the LONGITUDE BOTH AT SEA and LAND,

Humbly Proposed to the Consideration of the PUBLICK.

BY

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A

NEW METHOD

FOR

LONGITUDE

AT

SEA and LAND;

Nearly Proved to the Conviction of

the Publick.

TO

The Right Honourable THOMAS *Earl of* Pembroke *and* Montgomery.

The Right Reverend Father in God PHILIP *Lord Biſhop of* Hereford.

The Right Reverend Father in God GEORGE *Lord Biſhop of* Briſtol.

The Right Honourable THOMAS *Lord* TREVOR.

The Admirals of the Red, White and Blue Squadrons.

The Right Honourable EDWARD *Earl of* Orford, *Firſt Commiſſioner of the Admiralty.*

The Firſt Commiſſioner of the Navy.

The Firſt Commiſſioner of Trade.

The Maſter of Trinity-Houſe.

Sir THOMAS HANMER, *Bart.*

The Hon. General STANHOPE; *One of his Majeſty's Principal Secretaries of State.*

The Hon. FRANCIS ROBERTS, *Eſq;*

Sir ISAAC NEWTON, *Preſident of the Royal Society.*

WILLIAM LOWNDS, *Esq*;
WILLIAM CLAYTON, *Esq*;
Mr. JOHN FLAMSTEED, *Astronomer Royal.*
Dr. EDMUND HALLEY, *Savilian Professor of Geometry.*
Dr. JOHN KEILL, *Savilian Professor of Astronomy.*
Mr. NICOLAS SANDERSON, *Lucasian Professor of the Mathematicks.*
Mr. ROGER COTES, *Plumian Professor of Astronomy.*

Commissioners appointed by Act of Parliament for the Discovery of the LONGITUDE.

This New Method for that Discovery is with all due Submission humbly Dedicated by

The Authors.

THE
INTRODUCTION.

BEfore we come to give an Account of this our New Method for the Diſcovery of the Longitude, both by Sea and Land, which we here take leave humbly to propoſe to the Conſideration of the Publick, we think it reaſonable to premiſe ſomewhat by way of Introduction: To give ſome Account of the Nature of the Problem before us; to ſpeak a little of the Methods hitherto try'd, and the Reaſons of their ill Succeſs; and to add a brief Hiſtorical Narration from what Occaſions and by what Steps this

our

our Method was firſt diſcover'd, and has arriv'd at its preſent Degree of Maturity.

As to the Problem it ſelf, the Invention of the Longitude; it is plainly this: To diſcover in ſome meaſure a like ſure way of frequently knowing how far we are diſtant, on the Earth Spherical Surface, in Degrees, from any known Meridian, Eaſtward or Weſtward; as we can eaſily know, almoſt at any time, how far we are diſtant, in Degrees, on the ſame Surface, from the middle Circle or Equator, Northward or Southward. Now in this Caſe it muſt be noted, that as the Diurnal Motion does naturally imply fixed Poles, and a fixed Equator; which infer a different Meridian Altitude of thoſe Poles, and of that Equator, and by conſequence of all the heavenly Bodies, in different Latitudes; which different Altitude may in clear Weather be eaſily obſerv'd by proper

Inſtru-

Inſtruments, and thereby that Latitude may be readily diſcovered; ſo does not the ſame Diurnal Motion at all imply any *Phænomena*, whence the Longitude may be diſcover'd to us: Becauſe the ſame Parallel ſtill bears, through its whole Circumference, the ſame Relation to thoſe Poles and that Equator, without any Difference. The Diurnal Motion therefore, which affords an obvious Foundation for the Invention of the Latitude of every Place on the Earth, affords us no ſuch Foundation for the Invention of the Longitude of the ſame Places. Nor is it therefore an eaſy Problem, either aſtronomical or practical to diſcover the ſame.

As to the Methods hitherto tryed, they are either Celeſtial, or Terreſtrial; and may be reduc'd to theſe Seven, Four that are *Celeſtial*, and Three that are *Terreſtrial*.

(1) The Eclipſes of the Moon.

(2) The Eclipſes of the Sun.

(3) The

(3) The Eclipſes of Jupiters Planets.
(4) The Motion of the Moon.
(5) The Variation of the Needle.
(6) Clocks, or Watches.
(7) The Log Line or Dead Reckoning.

Firſt the Eclipſes of the Moon are uſeful for the Longitude. For its Immerſions into the Earth's Shadow, its neareſt Diſtances to that Center, and its Emerſions therefrom, are all at diſtinct and known Points of abſolute time. So that where and when they can be nicely obſerv'd; and the Difference of the apparent times at every Meridian noted; the reſpective Longitudes of thoſe Places may be thereby found in time; and by allowing 15 Degrees of the Equator to an Hour, may be found in Degrees alſo.

Secondly, in the ſame manner may the Eclipſes of the Sun be made uſe of; eſpecially as now improv'd by our great Aſtronomer Mr. *Flamſteed*'s

Conſtruction

Conſtruction of them; and as they will, we hope, be farther improv'd by Mr. *Whiſton*'s actual *Exhibition* of them, in his Inſtrument, juſt Publiſhed. Which Method, by the Difference of the apparent time of any Part of the Eclipſe in different Places, gives the Difference of Meridians, or of Longitude in the like manner as before.

Thirdly, the Eclipſes of Jupiters Satellits afford another like Method for the Diſcovery of the Longitude; and that on the ſame Foundation with thoſe of the Moon.

Fourthly, the Motion of the Moon, with its Diſtance from the Sun, or rather its Appulſe to and Occultation of thoſe fixed Stars that ly along its Courſe, is another remarkable Method for this purpoſe; and is of the ſame Nature with the Eclipſes of the Sun as to this matter.

Theſe Four may juſtly be called *Celeſtial*, or *Aſtronomical* Methods of

dicovering the Longitude, becauſe they make uſe of the Celeſtial Bodies, or of the Stars in order to that End. The Three *Terreſtrial* Methods are as follows.

5ly, The Variation of the Needle from the North is now, eſpecially ſince Dr. *Halley*'s noble Obſervations and Map thereto relating, become one Method for the Diſcovery of the Longitude; particularly in thoſe Parts where that Variation is beſt known, and the North and South Poſition of its Lines are moſt remarkable. For by croſſing the Meridians there, you alſo croſs the Curves of equal Variation, and diſcover in ſome meaſure your Longitude thereby.

Sixthly, The Uſe of Clocks or Watches at Sea is another Method; and was attempted by the famous *Hugenius*. And indeed if they could be exactly kept to an even motion, and ſo ſhew the Hour at any one certain place at Land; the Com-

pariſon

pariſon of the Time known by that Clock or Watch, with the apparent time at the Ship known by the Sun or ſtars, or another Clock or Watch regulated by them, would diſcover the Longitude from the Place to which that firſt Clock or Watch was adjuſted, in time, and ſo, as before, in Degrees alſo.

Seventhly, The Log-line and Dead Reckning, when all fails, is the laſt Remedy in this caſe; and from thence the Seamen gueſs, as well as they can, by the Angle and length of their Courſe, what Longitude and Latitude, they are in: And when by Obſervation they find their Error in Latitude, they conclude upon a proportionable one in Longitude alſo. And ſo for want of a ſure Guide, either Celeſtial or Terreſtial, they are forc'd to depend on this; which yet is, as well as the reſt, very uncertain and inaccurate.

For to come to the Reaſons of the ſmall Succeſs of theſe ſeveral Methods.

As to the two firſt, the Eclipſes of the Sun and Moon; to ſay nothing here of the ſlowneſs of the Moon's Motion, which renders any great degree of exactneſs impoſſible; or of the difficulty of Calculations and Conſtruction, eſpecially in the Sun's Eclipſes; and of Obſervations in both: The ſingle rareneſs of theſe Eclipſes, which is not ſeldom made ſtill rarer by cloudy Weather, renders them of very little uſe in Navigation.

As to the third Method, by the Eclipſes of *Jupiter*'s Planets; this muſt be own'd of much greater uſe: Since the quickneſs of their Motion, eſpecially as to the innermoſt, makes the Moment of their Immerſion into, or Emerſion from *Jupiter*'s Shadow very diſtinct and nice; and their frequency, which is almoſt one for every Day, renders them fit for the conſtant uſes of Navigation. Nor

have we hitherto had any other Method ſo uſeful at Land as this. Yet are there great Difficulties belonging to this Method; eſpecially at Sea. The beſt Tables of their Motions are hitherto too imperfect to be at all times depended on, as to the exact abſolute Time of their Celebration: And they require Teleſcopes of ſuch a length as have not hitherto been manageable at Sea, in that ſtate of Toſſing and Agitation which Ships there are ſubject to: Which difficulties, added to the impoſſibility of ſeeing theſe Eclipſes for about three Months every Year, when *Jupiter* is near the Sun, renders this Method at preſent of ſmall uſe in Navigation.

Nor can the fourth Method, or the diſtance of the Moon from the Sun, with its Appulſe to, or Occultation of thoſe fixed Stars which lye along its courſe, give us the Longitude to ſufficient exactneſs, for to ſay nothing here of the ſlowneſs of the Moon's

Motion,

Motion, the want of the utmoſt accuracy of even the place of ſome of theſe fixed Stars themſelves, and of the Sun it ſelf; or of the neceſſity of the uſe of ſmaller Teleſcopes, even in this Caſe; as well as of the trouble of the Calculation and Conſtruction, which are leſſer Difficulties here alſo; 'Tis plain the Theory of the Moon, eſpecially in ſome poſitions, is not exact enough hitherto for our purpoſe; as not ſerving for this Longitude nearer than to two or three Degrees: whereas the Seamen want it within one Degree, or leſs. Tho' indeed it muſt be allow'd, that if the Moon's Theory could be once ſo far perfected, that its place might be with certainty calculated nearer than to two Minutes of a Degree, this would be a very uſeful Method in order to the Diſcovery of the Longitude at Sea. Which Improvement therefore of its Theory is a thing highly deſireable in Aſtronomy.

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We come now to the *Terreſtrial* Methods, and to thoſe difficulties which render them alſo incapable of diſcovering the Longitude, with that certainty, and to that degree of exactneſs which the purpoſes of Navigation require. Thus the Curve lines of the Variation of the Needle, which is the firſt Terreſtrial Method, are of ſmall uſe, becauſe the Laws of that Variation are not yet brought to a ſufficient certainty, notwithſtanding the moſt uſeful endeavours of Dr. *Halley* in that Matter: The Neighbourhood of Iron Mines, of Iron, or of Loadſtones themſelves, does ſometimes diſturb the general Rules, and deceive the Obſervers of that Variation: The Poſition of thoſe Curves, too far Eaſtward and Weſtward, in a great part of the World, renders this Variation uſeleſs as to any general Diſcovery of the Longitude: and even there where the Poſition of theſe Curves is the moſt advanta-

geous

geous, as it is about the *Cape of Good Hope*, and a conſiderable way on both ſides of it, yet is the diſtance of thoſe Curves for the difference of one Degree of Variation, about 100 Geographical Miles, *i.e.* near two Degrees of a great Circle; and ſo this Method is incapable of ſhewing the Longitude very nicely in any Caſe whatſoever.

Thus the Second Terreſtrial Method, by Clocks or Watches, tho' the eaſieſt to underſtand and practice of all others, has been ſo long in vain attempted at Sea, that we ſee little Hopes of its great uſefulneſs there. Watches are ſo influenc'd by heat and cold, moiſture and drought; and their ſmall Springs, Wheels and Pevets are ſo incapable of that degree of exactneſs which is here requir'd, that we believe the beſt Mechanicks have the leaſt expectation from them in this Matter. Clocks govern'd by long Pendulum's go much truer: But then the difference of Gravity in different

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Latitudes the lengthening of the Pendulum-rod by heat, and ſhortening it by cold; together with the different moiſture of the Air, and the toſſings of the Ship, all put together, are circumſtances ſo unpromiſing, that we believe Wiſe Men are almoſt out of hope of Succeſs from this Method alſo.

And as for the Log-Line, and Dead-Reckoning, which is the third Terreſtrial Method, they were the known deficiencies of this common way, as alter'd by Storms, and Currents, and the Inaccuracies of the way it ſelf, and of even the Latitude, as commonly taken; together with the too frequent and enduring cloudy Weather, when they can take no Latitude at all; which have occaſion'd the Seamen to deſire ſome other Aſſiſtance for the Diſcovery before us.

We now come to our laſt Buſineſs, *viz.* to give the World a ſhort Hiſtory of our own Propoſal; from what oc-

caſions, and by what ſteps this our Method was firſt diſcover'd, and has arriv'd at its preſent degree of Maturity. As to which matter, the Reader is to know, that ſomewhat above a Year ago, Mr. *Whiſton* and Mr. *Ditton*, with ſome other common Friends, ſpent part of an Afternoon and the Evening together. Mr. *Ditton* took an occaſion, among other common diſcourſe, to obſerve to Mr. *Whiſton*, that 'The nature of Sounds would 'afford a method, true at leaſt in 'Theory, for the diſcovery of the 'Longitude; ſince *The difference between the apparent time where the Sound is made, and where it is heard; abating only the time for its diffuſion, which was now well known; is the difference of the Longitude of thoſe two Places in time.* Mr. *Whiſton* immediately own'd the truth of the Propoſition, and added, 'That as to the Pro-'pagation of Sounds, he remem-'bred to have himſelf plainly heard 'the Exploſion of great Guns a-

'bout

'bout 90 or 100 Miles, *viz.* when 'the *French* Fleet was engag'd with 'Ours, off *Beachy-head* in *Suſſex*; '[which was *A. D.* 1690.] and 'himſelf was at *Cambridge*; and that 'he had been inform'd, that in one 'of the *Dutch* Wars, the ſound of the 'like Exploſions had been heard in-'to the very middle of *England*, at 'a much greater diſtance. Upon 'this, Mr. *Whiſton*, when they part-'ed, told Mr. *Ditton*, that he took 'the thing to be ſo conſiderable, that 'tho it had been diſcourſed of in 'mix'd Company, after an unguard-'ed manner, yet he look'd on it as 'fit to be conceal'd; ſince no body 'could tell what Improvements might 'on farther Conſideration be built 'upon ſuch a Foundation. Which Advice Mr. *Ditton* follow'd; and accordingly deſir'd and obtain'd the Silence of thoſe that had then heard what had paſs'd. This Propoſition about Sounds, and their diſtant Pro-

pagation, with reſpect to the Longitude, did upon this ſo fix it ſelf in Mr. *Whiſton*'s Mind, and did occaſion ſuch Improvements there, that in leſs than two Days time he brought a ſmall Paper to Mr. *Ditton*, containing a Scheme, how that Theory of Mr. *Ditton*'s about Sounds might be reduc'd to Practice, and be actually apply'd to the diſcovery of the Longitude at Sea; which was then not much unlike the former branch of the following Eſſay, only more imperfect: Which Scheme Mr. *Ditton* approv'd of. Soon after this Mr. *Ditton* imparted this Diſcovery to a very good Friend, belonging to the Admiralty, in order to gain farther light as to its practicableneſs at Sea; and that proper Queſtions might by him be ask'd of Seafaring Men relating thereto, without any Suſpicion; which could not well be avoided if we our ſelves had ask'd them; eſpecially ſince the Notion was then

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got abroad that we had a Project about the Longitude to propose to the World. The result of this Enquiry was, that those Sea-men our Friend enquir'd of, did not remember to have heard Sounds at Sea any whit near so far as the before-mention'd Examples shew'd they had been heard at Land; which difficulty put some stop to our Progress for a little while. However, at last, after farther enquiry, the final result was this, That tho' Sounds were not ordinarily either at Sea or Land heard very far, yet that was not at Sea more than at Land any certain Argument that they could not spread so far; because Sounds had been heard a full Degree at least, or 60 Geographical Miles over Sea, even without any extraordinary Contrivance, either at the sounding Body, or the Ear; both which were yet, for certain, capable of great improvements, in order to the enlargement of that

distance.

diſtance: So that the Objection ſtarted againſt the ſpreading of Sounds at Sea ſeem'd to be in a manner over, and we at liberty to proſecute our Deſign, as before, of diſcovering the Longitude by means of it. About this time Mr. *Whiſton* diſcover'd and propos'd a great Improvement of his own to this Method; *viz.* That the Guns which where to make the Exploſions in the former Caſe, might alſo carry Shells, full of Powder, or ſuch other combuſtible Matter as would take fire at the utmoſt Altitude; and thereby certainly and exactly exhibit the point of the Azimuth, and the Diſtance of the ſounding Body; and ſo join the uſe of the Eye and Ear together for the ſame purpoſe. Tho' at the firſt he muſt own he ſuſpected that the Apparent Diameter of that Light or Fire would in great diſtances be ſo ſmall as not to be there viſible. In this very juncture a day of extraordinary Fire-

works

works happen'd [it was the Thankſgiving day for the Peace, *July* 7th, 1713.] the Contemplation of which, did much revive and encourage this Notion: and the certain Account he ſoon had that thoſe Fire-works, nay, the ſmall Stars into which the Rockets commonly reſolv'd themſelves, where plainly viſible no leſs than 20 Miles, put an end to his doubts immediately; and made him very ſecure that ſuch large Shells as might be fir'd at a vaſtly greater height, would for certain be viſible for about 100 Miles; which he look'd on as nearly the limit of Sounds alſo, as to any purpoſes of Longitude. And this has been ſince abundantly confirm'd by experiments made by Mr. *Whiſton*'s own Directions. Thus on *Saturday*, *Aug.* 8th. laſt four ſeveral Rockets were by him and many others ſeen about 30 meaſur'd miles; and that ſo very plainly, that 'tis highly probable they might have been ſeen

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at leaſt 10 if not 20 Miles farther, in a proper Elevation. Thus alſo the Light of a Ball of Fire of ſeven Inches diameter, which has been ſeveral times thrown up from a ſmall Mortar at *Black Heath*, has been ſeen in ſeveral Counties at the diſtance of Fifty and Sixty, if not Seventy, meaſured Miles. This Improvement of Mr. *Whiſton*'s, which was alſo then for the main the ſame with the ſecond Branch now contain'd in this Paper, was alſo approv'd of by Mr. *Ditton*, and agreed to as fit to be a part of the former Deſign for the Diſcovery of the Longitude at Sea. Mr. *Ditton* did farther add, for Improvement, a ſure Method of Trigonometrical Calculation, to aſcertain from the Obſervations the horary Difference of Meridians (and by conſequence the Difference of Longitude in Degrees) between the Ship's Place, and that of Exploſion; without computing the Time of the Sound's

Sound's propagation: but since this Method is somewhat more operose than that which is propos'd hereafter, he chooses to omit it. He did also first observe that great Use of our Method at Land, in the Surveying of Countries, for the Perfection of Geography; which was also readily taken notice of by Sir *Isaac Newton*, and afterwards by Dr. *Halley*, and that both of their own accord, upon our first communication of our Method to them. For when Matters were brougt to so hopeful a Posture, and necessary Tables were preparing for the actual Practice of the whole Method, we began to think of intimating to the Publick, that we had a new Discovery, as to the Longitude, to propose to the World. Which we soon did, by our Letter inserted in the Paper call'd the *Guardian*, of *July* 14, and repeated by another in the same Author's Paper call'd the *Englishman*, of *December* 10.

following: Having before communicated the matter to the illuſtrious Sir *Iſaac Newton*, as we did afterward to thoſe great Men, Dr. *Clarke* Rector of St. *James*'s, Dr. *Halley* of *Oxford*, and Mr. *Cotes* of *Cambridge*. How far we profited by this Communication, and what their Opinions were concerning our Method, we need not ſay: becauſe we do not give an Account here of every occaſional Improvement, either of our own or others; and becauſe we now publiſh the intire Method, as it ſtands at preſent, to the whole World, for every one's open Judgment, and the farther Improvements of the skilful. Only ſo far their Opinions and Declarations appear to have been on our ſide, that upon hearing what they and we had to ſay, the Committee of the Houſe of Commons, which was appointed to inquire into this matter, came unanimouſly to a Reſolution in our Favour; and the Legiſlature have there-

thereupon thought fit to paſs an Act, appointing a noble Reward for ſuch as ſhall diſcover a better Method than has been hitherto us'd for the finding the Longitude. Which Reward, whether we have any juſt Claim to, in whole or in part, we do hereby intirely ſubmit to the Sagacity and Juſtice of thoſe eminent Perſons whom the Legiſlature has been pleas'd to intruſt with the Tryal, Experiment, Judgment, and Determination of all ſuch Propoſals.

It muſt here be Obſerv'd, before we conclude, that this Method, as it was at firſt publiſhed, ſuppos'd the direct fixing of Hulls at Sea: which appearing very difficult in Practice, Mr. *Whiſton* from ſeveral Hints he met with in converſing with Perſons skill'd in Sea-Affairs, and his own Study of the Geometrical Part of managing of Ships, made another great Improvement, and contrived all ſo, that thoſe *Hulls* might be ſpar'd,

and any ſmall *Stationary Ships* might ſuffice: and that inſtead of fixing ſuch a Hull; a Buoy, or Float, or Sea-Mark only ſhould be really fix'd; and the Stationary Ship ſhould do no more than keep it ſelf near the ſame: which it is eaſy to do within the diſtance here neceſſary. And this after ſuch a manner, that if the Ship were at any time driven away, it ſhould readily recover its former Station again; as it now ſtands in this ſecond Edition. It muſt alſo, in Juſtice, be obſerv'd, that when Mr. *Whiſton* and Mr. *Ditton*, a little before the Sickneſs and Death of the latter, came to communicate this Improvement, which was generally approv'd of, to the Right Honourable the Earl of *Pembroke*; who, as is moſt gratefully to be acknowledged, has all along ſhew'd a peculiar Readineſs and Sagacity in bringing this Propoſal to bear, and in clearing it of all ſuch Difficulties as did incum-

ber

ber it; His Lordſhip appeared to be already Maſter of it, and propos'd it to us as his own Thought. Nor is it fit to omit the other very conſiderable Information we at the ſame time received from his Lordſhip, of which we had ſome, but that very uncertain and imperfect Intimation before, *viz.* That it has actually appear'd upon Tryal, that the Ocean between *Europe* and *America* is no where above 300 Fathom deep, excepting near the Mouth of one of the great Rivers of the other Continent: where yet 'tis more likely the Strength of the Stream, by carrying the Line more oblique, occaſion'd it to ſeem deeper than the reſt than that it really was deeper in that particular Place. His Lordſhip alſo gave us Directions where to find this Account alſo; tho' we have not hitherto been able to light on the Book refer'd to by his Lordſhip. Yet do we not at all doubt of the

Truth

Truth of the Experiment; and do thereby find that our Buoys may therefore, in all Probability, be always fix'd by the ſure Method of Anchors: which we were not before ſo well ſatisfy'd of. Which Obſervation is of great Uſe for the compleating our preſent Diſcovery.

We conclude all with our hearty Wiſhes as *Men*, that this our Deſign may tend to the common Benefit of Mankind: as *Britains*, that it may tend particularly to the Honour and Advantage of this our Native Country; and as *Chriſtians*, that it may tend to the Propagation of our Holy Religion, in its original Purity, throughout the World.

William Whiſton, *Humphry Ditton*.

PRO-

PROBLEM.

To find the LONGITUDE both at Sea and Land.

LEMMATA, *or Preparatory Propoſitions.*

I. ALL Sounds are propagated almoſt evenly; and are obſerv'd to move in calm Weather very exactly 8 Meaſur'd Miles in 37 Seconds of Time: *i. e.* one Geographical Mile or Minute of a Degree in $5''\frac{1}{3}$.

This is well known from the laſt and the moſt accurate * Obſervations

* *Philoſ. Tranſact.* N°. 247. *Sir* Iſaac Newton's *Princip. Edit.* 2. *p.* 343, 344.

about

about the Velocity of Sounds, which are thoſe of the Induſtrious and Skilfull Mr. *Derham*. Only a ſmall Addition of Velocity is to be made, when a ſtrong Wind carries the Sound with it, and Subſtraction when it oppoſes it; and that, as thoſe Obſervations Shew, in the Proportion of the winds velocity to that of the Sound; which is hardly ever ſo great as One to Twelve.

II. The Sound of the greateſt Guns may be heard by the Ear, duly aſſiſted, if the Wind be favourable, or ſtill, both by Sea and Land, at the leaſt 100 meaſur'd, or 85 geographical Miles. In the open Sea alſo, the Point of the Compaſs may be nearly determin'd whence it comes.

This is very probable, as to the Diſtance, from many known Experiments*; wherein the Ear, even un-

* See *Philoſ. Tranſact.* p. 156, 201, 247.

aſſiſted,

assisted, has heard such Sounds much farther. And if the Sound were increas'd by a sounding Board, which might prevent its diffusion upwards, and so spread it farther Horizontally on all sides; and if the Ear were assisted by a hollow Tube of Metal, of the shape of a Bell or Tunnel, apply'd thereto, this Proposition would soon be more indisputable. Nor is there any great Dificulty, as to the Point of the Compass, whence the Sound comes at Sea, where nothing can reflect or echo the same in any other than the true Angle.

III. The Distance of the sounding Body, where the Sounds are of the same Strength, and Tenor, and Circumstances, may, within some Latitude, be determin'd by the Ear, duly assisted, and frequently exercis'd in such Observations; even at very considerable Distances from the sounding Body.

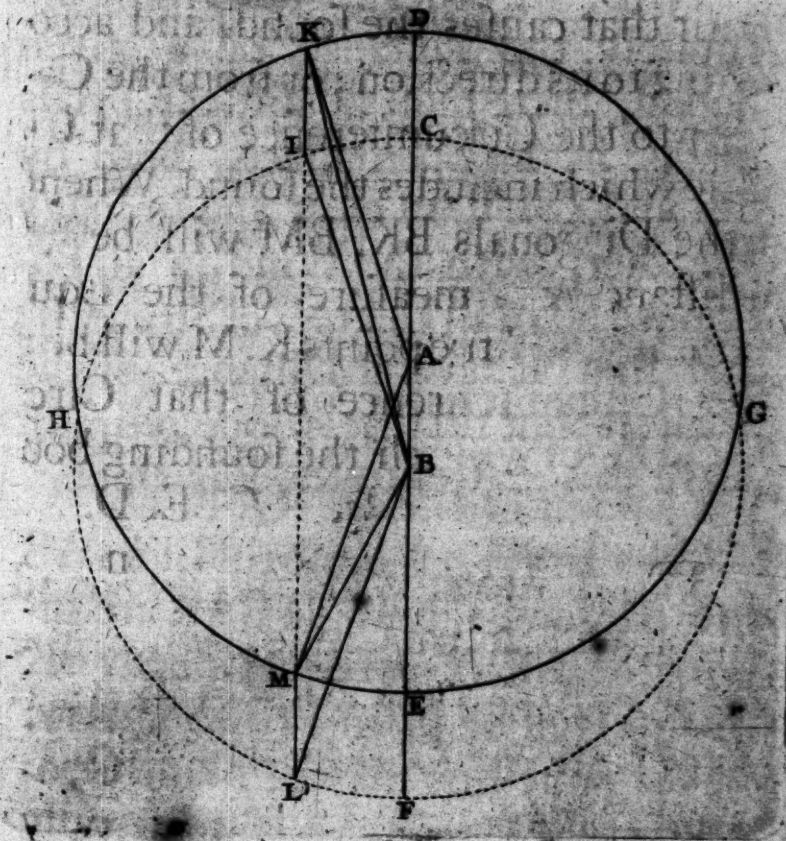
This appears from the obvious difference of the ſame Sounds at very different Diſtances at preſent; which Sounds are in a duplicate Proportion of thoſe Diſtances reciprocally. And from the great Improvements, Experiments made on purpoſe would probably afford us therein.

N. B. In order to determine accurately the Diſtance of a given Sound, there muſt be diſtinct Trials made, in an open Place, both by Sea and Land, in clear and in foggy Weather, with the Wind in all Poſitions, and of all Degrees of Strength; and this at ſeveral Diſtances of the Hearers: but till that is done, we muſt leave this matter to the Ear alone.

IV. A ſtrong Wind carries Sound along with it in a Circle; where the Sounding Body is a Point in its Axis: and is more or leſs remote from its Center,

Center, according as the Wind is greater or leſs.

This appears by the Demonſtration following. Let the Proportion of the Velocity of the Wind, to the Velocity of the motion of the Air that cauſes the Sound, be as A B to A D.



Let the two equal Circles GD HE, GCHF, be deſcribed upon the Centers A and B; and let any Line, as KL, be drawn Parallel to DF. KI will therefore be always equal to ML, or to the Velocity of the Wind, and according to its direction: as AM = AK = BL = BI will be equal to the Velocity of the Motion of the Air that cauſes the ſound, and according to its direction; or from the Center to the Circumference of that Circle which includes the ſound. Whence the Diagonals BK, BM will be the diſtance or meaſure of the Equal ſounds; and the points K. M will be in the Circumference of that Circle GD HE of which the ſounding body B is a point in its Axis. Q. E. D.

Corollary (1.) Becauſe the Lines AB and AK, and the Angle BAK are given; the diſtance of equal ſounds BK is alſo given by plain Trigonometry. As the ſame line may be found Geometrically

metrically alſo by applying its length to a ſcale of equal parts.

Coroll. (2.) Two equal Circles, ſliding one upon the other, according the direction of the Axis FD is the readieſt way of ſolving this Problem, for the uſe of Seamen; as being ſo very eaſy in Practice.

V. The Interval of apparent time, in two places, where a Sound is excited, and where it is received; beſides that which is due to the real propagation of the Sound it ſelf; is the Difference of their Meridians, or of their Longitude in Time.

Thus if a Sound, excited juſt at 12 a clock at one place, comes to another after the very ſame Time that is due to the Sounds propagation, as at the diſtance of about 13 meaſured Miles, one minute after 12. At the diſtance of 26 ſuch Miles, two minutes after 12. &c.

&c. 'tis evident the places are under the ſame Meridian, and have no difference of Longitude. But if it be heard ſooner or later than thoſe times, the Difference is what anſwers to the Temporary difference of their Meridians, or of Longitude, Weſtward or Eaſtward: and ſo is a ſure indication of the ſame. As is very obvious on a little conſideration; and as we ſhall ſhew preſently by example.

VI. A Moderate Mortar, with a Moderate Charge of Powder, is able to caſt a projectil near two meaſur'd miles, or 10000 Engliſh feet in perpendicular height.

This appears by that known * Theorem in the Art of Gunnery, which demonſtrates, that the utmoſt Altitude is always equal to half the utmoſt Random of the ſame Gun and

* *Halley ap. Tranſact. Philoſoph.* N° 179. Mr. Apderſon's *Gunn. paſſim.*

Powder:

Powder: which utmoſt Random, of ſuch a Mortar, with a competent charge of Powder, is known to be near four meaſur'd miles, or 20000 feet.

And Since we have already tryed a very ſmall Mortar, and find that with one Pound and an half of ſtrong Powder it caſts up a Shell of above 20 Pound weight not much ſhort of a meaſured Mile high, there is no reaſon at all to doubt of the Truth of this Propoſition.

N. B. That it appears, by the ſame way that the largeſt Great Guns, with their largeſt charge of Powder, may probable be able to caſt a Projectil twice ſo high. But becauſe the charges and trouble are in ſuch caſes much greater; and it is uncertain whether the advantages will be proportionably augmented, we chooſe to ſpeak moderately; and to propoſe nothing here but what is for certain cheap, practicable, and advantagious; and leave thoſe

thoſe more ſurprizing heights, to the conſideration of the publick afterward: Only with this obſervation, that the Altitude will ever be as the Squares of the Velocity, with which the Projectil is thrown. *i. e.* With double and triple velocity, the Altitude will be four and nine times as great as before reſpectively; and ſo for ever.

VII. The time of the Aſcent or Deſcent of ſuch a Projectil; without the conſideration of the reſiſtance of the Air; (which in the caſe of lead bullets, iron ſhels, or the like denſe bodies, is but very ſmall, and in Wood not very great;) is 25″: and is always the ſame in the ſame height.

This appears from the known Velocity of deſcending or aſcending bodies *, which fall or riſe 16′1 Eng-

* Ubi Supra.

liſh

fifth Feet in one ſecond of time; and by conſequence 6400 Feet in 20". and 10000 in 25". thoſe lines of deſcent or aſcent being ever as the Squares of the Times.

VIII. Gunpowder may be diſcharged, or combuſtible matter ſet on Fire at that utmoſt height.

This all that deal in Rockets, Bombs and Mortars do very well know. It being the great buſineſs of their Art to proportion the Match or Fuſee to any particular time when it ſhall give Fire; which may as well be always adjuſted to 20" or 25" as to any other number. Nor indeed is it impoſſible to contrive all ſo, that the very beginning of the deſcent ſhall be immediately inſtrumental in that matter, and thereby render the Experiment more exact and infallible.

IX. Fire or Light, if it be ſtrong enough, and 6400 Feet high, will be viſible, in the night time, when the Air is tolerably clear, about 100 meaſured, or 85 Geographical Miles: *i. e.* one whole degree, and 25 minutes of a great Circle, from the place where it is, even upon the ſurface of the Sea. And if it be 10000 feet high, it will be viſible 123 meaſur'd, or 106 Geographical miles, in the ſame Circumſtances.

This is eaſily deduced from the Tables of Tangents and Secants, applyed to our Earth; as will appear preſently. Only it may be noted that the Refraction of Light out of the ſomewhat thinner Air above, into the ſomewhat thicker Air beneath, increaſes this diſtance a little; as alſo that an Eye upon the Maſt of a Ship will ſee ſuch Fire or Light about 10 Miles

Miles farther than one on a Level with the Surface of the Sea; as will appear presently also.

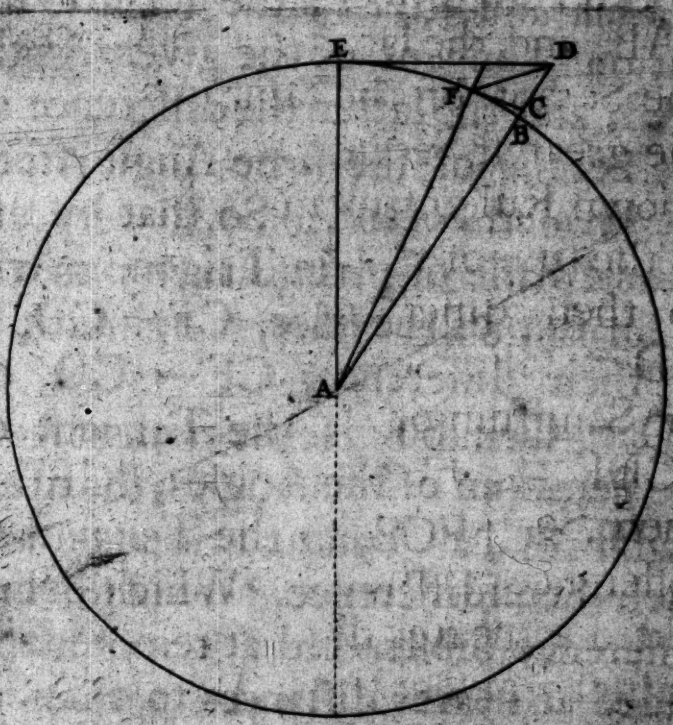
N. B. That the Distances this Fire or Light can be seen, abating the consideration of the Atmosphere, are nearly in a subduplicate proportion of the Altitudes; and so at twice the greatest height already mentioned, to which yet we have observed Projectils may be thrown, this distance will be larger in the proportion of 10 to 7; *i. e.* about 176 measured, or 151 Geographical Miles; even without the allowance for refraction, or for the elevation of Mountains, whereon such Mortars or Guns may be plac'd: both which, when allowed for, will imply, that 'tis possible, if the light be strong enough, to extend this distance to full 200 Geographical Miles, or minutes of a great Circle. A vast extent this! and capable of affording proportionably vast advantages

to Mankind, upon the preſent foundation!

X. The Angle ſuch fire or light is ſeen above the Horizon will very exactly diſcover its diſtance; as will an eaſy obſervation its Azimuth.

The former branch is evident from the nature of a Sphere, with the uſual Tables of Tangents and Secants: and may thus be computed by plain Trigonometry. Suppoſing the eye of the Spectator placed at the ſurface of the Sea; and not conſidering the very ſmall difference by the refraction.

Let A repreſent the Earth's Center, BD the length of the Secant of 1°. 25'. or 1°. 46' above the Radius; *i. e.* 6400 or 10000 feet. ED the Tangent of the ſame Angle. CB the length of the Secant above the Radius, at any leſſer Angle, as BAF. and CF the Tan-



Tangent of that laſt Angle. 'Tis evident that the Angle DFC is the elevation of the fire or light above the horizon at any given Point F. and that in the plain Triangle DCF the Angle DCF is given, equal to a right Angle, and to the Angle FAB. FCB is its complement; and equal to the ſum of the remote Angles CFD, and CDF. The including ſides alſo CF

and

and CD are given; the former being the Tangent of the given Angle FAB, and the latter the difference of the Secant of the ſame Angle from the greateſt Secant. So that by the known Rule of plain Trigonometry, as the ſum of the ſides, CF + CD, is to their difference, CF − CD, or CD − CF: So is the Tangent of the Semiſum of the Angles, ½ CFD + ½ CDF = ½ FCB, to the Tangent of their Semidifference. Which Semidifference ſubſtracted at remoter and added at nearer diſtances to that Semiſum; gives the Angle ſought CFD. Q.E.I.

According to this Rule the following Tables are made to every Minute, or Geographical Mile; for the eaſe of all that may uſe this Method, and may deſire ſome exactneſs therein.

Table

Table the firſt, for the utmoſt Altitude of 6400 feet, and 40″.

Miles diſtance	Angle above the Horizon.	Miles diſtance.	Angle above the Horizon.
1	46——25	29	1——50
2	27——42	30	1——46
3	19——16	31	1——41
4	14——40	32	1——37
5	11——50	33	1——33
6	10——20	34	1——28
7	9—— 0	35	1——24
8	7——55	36	1——20
9	6——50	37	1——17
10	5——55	38	1——14
11	5——20	39	1——12
12	4——54	40	1——10
13	4——30	41	1—— 7
14	4—— 8	42	1—— 4
15	3——52	43	1—— 1
16	3——37	44	0——59
17	3——23	45	0——57
18	3——11	46	0——55
19	3—— 0	47	0——53
20	2——50	48	0——51
21	2——41	49	0——49
22	2——33	50	0——47
23	2——25	51	0——45
24	2——18	52	0——43
25	2——12	53	0——41
26	2—— 6	54	0——39
27	2—— 1	55	0——38
28	1——55	56	0——36

Miles distance.	Angle above the Horizon.	Miles distance.	Angle above the Horizon.
57	0——34	72	0——14
58	0——32	73	0——13
59	0——31	74	0——12
60	0——30	75	0——11
61	0——28	76	0—— 9
62	0——26	77	0—— 8
63	0——25	78	0—— 7
64	0——24	79	0—— 6
65	0——23	80	0—— 5
66	0——21	81	0—— 4
67	0——20	82	0—— 3
68	0——19	83	0—— 2
69	0——18	84	0—— 1
70	0——17	85	0—— 0
71	0——15		

Table the second, for the utmost Altitude of 10000 feet, and 50".

Miles distance.	Angle above the Horizon. ° ″	Miles distance.	Angle above the Horizon. ° ″
1	58——32	10	9——12
2	39——14	11	8——22
3	28——23	12	7——40
4	22——11	13	7—— 3
5	18—— 4	14	6——32
6	15——11	15	6—— 5
7	13——16	16	5——42
8	11——41	17	5——21
9	10——21	18	5—— 2

Miles

Miles distance.	Angle above the Horizon. ° ′
19	4 — 46
20	4 — 30
21	4 — 16
22	4 — 4
23	3 — 53
24	3 — 42
25	3 — 32
26	3 — 22
27	3 — 14
28	3 — 6
29	2 — 59
30	2 — 52
31	2 — 46
32	2 — 40
33	2 — 35
34	2 — 30
35	2 — 25
36	2 — 20
37	2 — 15
38	2 — 10
39	2 — 5
40	2 — 1
41	1 — 57
42	1 — 53
43	1 — 49
44	1 — 45
45	1 — 42
46	1 — 39
47	1 — 36
48	1 — 33
49	1 — 30
50	1 — 27

Miles distance.	Angle above the Horizon. ° ′
51	1 — 24
52	1 — 21
53	1 — 18
54	1 — 15
55	1 — 12
56	1 — 10
57	1 — 8
58	1 — 6
59	1 — 4
60	1 — 2
61	1 — 0
62	0 — 58
63	0 — 56
64	0 — 55
65	0 — 53
66	0 — 52
67	0 — 50
68	0 — 49
69	0 — 47
70	0 — 46
71	0 — 44
72	0 — 43
73	0 — 41
74	0 — 40
75	0 — 38
76	0 — 36
77	0 — 34
78	0 — 33
79	0 — 31
80	0 — 30
81	0 — 28
82	0 — 27

Miles distance.	Angle above the Horizon. ° ′	Miles distance.	Angle above the Horizon. ° ′
83	0 — 26	95	0 — 11
84	0 — 24	96	0 — 10
85	0 — 23	97	0 — 9
86	0 — 21	98	0 — 8
87	0 — 20	99	0 — 7
88	0 — 19	100	0 — 6
89	0 — 18	101	0 — 5
90	0 — 17	102	0 — 4
91	0 — 15	103	0 — 3
92	0 — 14	104	0 — 2
93	0 — 13	105	0 — 1
94	0 — 12	106	0 — 0

N. B. It appears by these Tables that the distance will never be less exact in this Method than is the Observation of the Altitude; since one Mile here never corresponds to less than one Minute; but that generally the distance is much more exact than the Observation: Since one Mile commonly corresponds to considerably more than one minute; nay at very near distances to more than one whole Degree; as is evident by inspection. As for the observation

ſervation of the Azimuth, 'tis too eaſie to need any demonſtration.

N. B. If the Eye be elevated above the ſurface of the Sea, it will ſee the fire or light farther; according to the following Table.

Miles diſtance.	Elevation in feet.
1	1
2	4
3	8
4	15
5	23
6	34
7	45
8	57
9	71
10	88
11	107
12	128

XI. If the fire or light be rendred compleatly viſible during the intire time of the aſcent or deſcent, as in the ordinary Sky-rockets, its Diſtance may be exactly determin'd alſo from the time it appears above the Horizon, by the

use of the following Tables, even without the knowledge of the Angle of Elevation.

A Table of the number of feet that Bodies fall or rise, as far as 25". of Time.

"	feet.	"	feet.
1	16,1	½	2930
½	35,4	14	3156
2	64,4	½	3381
½	100	15	3622
3	145	½	3864
½	193	16	4122
4	259	½	4379
½	320	17	4653
5	402	½	4927
½	483	18	5216
6	580	½	5506
½	676	19	5812
7	789	½	6118
½	902	20	6440
8	1030	½	6762
½	1160	21	7100
9	1294	½	7438
½	1442	22	7792
10	1610	½	8147
½	1771	23	8517
11	1948	½	8887
½	2125	24	9273
12	2318	½	9660
½	2512	25	10062
13	2721		

N. B.

N. B. That if we allow in this Table the odd 40 and 62 feet, over againſt the greateſt Altitude, of 20″. and 25″. for the ſmall reſiſtance of the Air, we ſhall then have the even Numbers 6400 and 10000 feet for the real perpendicular Altitudes reſpectively; as we have all along ſuppos'd them to be.

A Table of the Exceſs of the Secants in Feet, above the Earth's Semidiameter, as far as 1°. 46″.

′	feet.	′	feet.
1	1	16	227
2	4	17	256
3	8	18	288
4	15	19	321
5	23	20	357
6	34	21	393
7	45	22	430
8	57	23	470
9	71	24	512
10	88	25	556
11	107	26	601
12	128	27	647
13	151	28	695
14	174	29	745
15	199	30	798

'	feet.
31	853
32	909
33	968
34	1026
35	1088
36	1151
37	1216
38	1283
39	1352
40	1422
41	1493
42	1569
43	1642
44	1720
45	1800
46	1882
47	1963
48	2047
49	2134
50	2222
51	2312
52	2404
53	2497
54	2592
55	2688
56	2787
57	2887
58	2991
59	3093
60	3198
61	3305
62	3415
63	3526
64	3639

'	feet.
65	3755
66	3870
67	3988
68	4118
69	4229
70	4353
71	4479
72	4608
73	4735
74	4866
75	4998
76	5132
77	5269
78	5407
79	5546
80	5687
81	5830
82	5974
83	6121
84	6271
85	6422
86	6573
87	6726
88	6882
89	7039
90	7199
91	7360
92	7522
93	7686
94	7852
95	8020
96	8190
97	8362
98	8536

′	feet.	′	feet.
99	8611	103	9429
100	8887	104	9614
101	9066	105	9799
102	9246	106	9986

N. B. The Rule for Practice is this: Obſerve the Number of the Seconds of Time that you ſee the Fire or Light, either aſcending or deſcending, in the former Table; with its correſponding Number of Feet. Take this Number of Feet out of the entire Number, and keep the Remainder. For where that Remainder is found in the latter Table, you will find the true Diſtance over againſt it. *e. g.* Suppoſe the Light or Fire is obſerv'd to take up 12″. or a fifth Part of a Minute, in its viſible Aſcent or Deſcent. The correſponding Number of Feet in the former Table of 6400 Feet for 40″. is 2318, which deducted from 6400, leaves 4082, for the Difference: Which Number in the other Table

Table correſponds to about 68′. and ſhews that the real Diſtance ſought, is about 68 Minutes, or Geographical Miles. And in the other Altitude of 10000 Feet for 50″. the correſponding Number of Feet is the ſame, 2318; which deducted from 10000, leaves 7682, for the Difference: Which Number, in the other Table, correſponds to about 93′. and ſhews that the real Diſtance is in that Caſe 93 Minutes, or Geographical Miles. The Demonſtration is eaſy from the former Scheme. For DB — DC = CB, and ſo DA — DC = CA. or the Difference of the largeſt Secant, and of any Part of it viſible in another Horizon, as at F, is equal to the Secant of that Angle DAF, or of the Arch BF, which is the Diſtance required. Only if the Bottom of the Atmoſphere be too thick to permit the Light or Fire to be ſeen to any certain Altitude,

tude, allowance muſt be made for the ſame, in the uſe of theſe Tables.

XII. When a Sound and a Light are made at the ſame Place, either at the ſame time, or at any given Interval; the Diſtance of ſuch Sound and Light from the Auditor or Spectator may be exactly determin'd.

For if they are made at the very ſame time, the Difference of the Velocity of Light, which is, phyſically ſpeaking, inſtantaneous, and of Sound, which goes Eight meaſur'd Miles in Thirty ſeven Seconds, will, with great Exactneſs, determine that Diſtance. And if there be a given Interval between them, it is eaſily allow'd for.

N. B. But for the greater eaſe and readineſs of knowing this Diſtance, wherever the Ball of Light or Fire is

viſible, either all the way up and down, or even barely up or down; the following Tables, deriv'd from the two foregoing, will, by Inſpection, immediately ſhew it, to every half Second of Time; both for the utmoſt Altitude of 6400 feet, and 40". and of 10000 feet, and 50". in caſe the Time be reckon'd half that which paſſes from the aſcent of the Body above the viſible Horizon, till its deſcent below it again; without any farther Trouble.

A Table of Miles diſtance from the Exploſion, for the Altitude of 6400 Feet and 40". as alſo for 10000 Feet and 50".

40". "	Miles diſtant.	40". "	Miles diſtant.
	½ 85	4	83
1	85		½ 83
	½ 85	5	82
2	85		½ 82
	½ 85	6	81
3	84		½ 81
	½ 84	7	80

40".

40″. ″	Miles distant.
½	79
8	78
½	77
9	76
½	75
10	73
½	72
11	71
½	70
12	68
½	66
13	64
½	62

40″. ″	Miles distant.
14	60
½	58
15	56
½	53
16	50
½	47
17	44
½	40
18	36
½	30
19	26
½	18
20	00

50″. ″	Miles distant.
½	106
1	106
½	106
2	106
½	106
3	106
½	105
4	105
½	105
5	104
½	104
6	103
½	103
7	102
½	102
8	101
½	101
9	100

50″. ″	Miles distant.
½	99
10	98
½	97
11	95
½	94
12	93
½	92
13	91
½	89
14	88
½	87
15	86
½	84
16	82
½	80
17	78
½	76
18	74

50".	"	Miles distant.	50".	"	Miles distant.
	½	72		22	50
	19	69		½	46
	½	66		23	41
	20	64		½	36
	½	61		24	29
	21	58		½	20
	½	54		25	00

N. B. If this Method by the Time be made uſe of in the greater, and that by the Altitude above the Horizon in the leſſer Diſtances, the Meaſures will be the moſt exact.

N. B. This Method by the Time is very eaſy for Practice; becauſe it requires only the counting of a few Seconds or half Seconds. Nor is that Inaccuracy which appears at near Diſtances of any great conſequence; becauſe the very gueſs at the Altitude will there ſufficiently correct it; and becauſe near the place of Exploſion there will be little occaſion for any nice Obſervations at all.

N. B. This Method, if it reach to aſcent and deſcent alſo, is alſo exceeding

ceeding uſeful; becauſe it will ſhew the Altitude and Diſtance, even when Clouds intercept the ſight of the Shell near the top, as will ſometimes happen: ſince the Time between the firſt and laſt ſight of the Shell in its aſcent above and deſcent below the Horizon, on which the whole depends, is not affected by it; *i. e.* wherever there is any ſpace between the Clouds and the viſible Horizon: otherwiſe there is no room for this Obſervation.

N. B. But becauſe the longer time the combuſtible Matter is in burning the leſſer muſt be its Light, the beſt way of all ſeems to be that of making it take Fire ſome time before it comes to the utmoſt Elevation, and to make it burn ſome time after. This will ſerve every Intention as near as may be. It will give the Diſtance by the Elevation every where: and alſo by the Time in remoter

moter Distances, where that last Method is chiefly useful.

XIII. If the Longitude and Latitude of one Place be known, and the Distance and Position of another be also known; the Longitude and Latitude of this other Place is known also.

This is too obvious to need a Demonstration; and may be easily shew'd on a Map, with a Pair of Compasses, apply'd to the Scale of that Map.

XIV. If the Longitude and Latitude of one Place be known, and its Distance from another be known also, and the Longitude of that other Place be otherwise known, its Latitude is thereby known. And if its Latitude be otherwise known, its Longitude is thereby known also.

This

This is alſo too obvious to need a Demonſtration ; and may be ſhew'd on a Map, as well as the foregoing.

XV. Buoys, Floats, or Sea-marks, near which Ships may keep their Stations, may be intirely fix'd at Sea in all ordinary Caſes, by Anchors ; and in extraordinary Caſes, where the Ocean is vaſtly deep, they may be nearly fix'd by Weights let down from them quite through the upper Currents into the ſtill Waters below, as near as poſſible to the Bottom.

This Matter belongs to Tryal and Experiments, and is not to be here particularly demonſtrated. Only we may obſerve, that the lower Parts of the Waters in the Ocean are commonly found to be free from the Currents and Motions of the higher Parts; and that the Method by which thoſe very Currents are diſcover'd,

is

is no other than by thus letting down the Lead far below them; which, tho' it touch not the Bottom, yet makes the Boat out of which the Lead is thrown, in the Words of an Eye-Witneſs, * *ride as firmly as if it were faſtened by the ſtrongeſt Cable and Anchor to the Bottom.*

N. B. If any Current or ſtrong Wind does, in ſome meaſure, carry away ſuch a Buoy, with any ordinary Leads, or Weights, care is to be taken that the Cord or Chain be upward as ſmall, and make as little Reſiſtance to the flowing Water as poſſible; and that the ſame Cord or Chain with its Weights or Leads below, be as large and cumberſome, and make as great Reſiſtance to the ſtill Water below, as poſſible: that ſo the Motion of the Buoy may be inſenſible. Note alſo that in caſe there appear ſtill ſome Motion in

* Philoſ. Tranſ. *No.* 36. *Abridg. Vol.* 3. *p.* 555, 556.

the

the Buoy, the Mariners are nicely to obſerve its Velocity and Direction; and at convenient Seaſons to bring it back again, as near as poſſible, to its original Station.

N. B. This Buoy, Float, or Sea-Mark may be a very ſtrong Circle of Planks, with a ſmall but ſtrong Maſt in the middle, of about 23 Feet high, ſupported by great Cables, as Braces on every ſide, and a bright Sphere and Lanthorn at the top, for its more eaſy and remote Diſcovery from the Ship.

N. B. This Buoy will be ſeen from the Maſt of a Ship 88 Feet high, by the former Table, *pag.* 51. at the diſtance of full 15 Miles, or any where within a Circle of 30 Miles Diameter, which is near 100 Miles in Circumference.

N. B. Since the Art of Navigation, and common Practice at Sea aſſure us, that a Ship can ſail above two Points towards the Wind; nay,

by plying in an indented Manner to Windward, can directly ſail againſt it; And ſince ſuch a Buoy will be ſo far viſible; it is evident, that when there is danger of a Storm, the Stationary Ship may go 15 Miles to Windward; and that then no Storm need drive it out of ſight of that Buoy, but ſuch an uncommon one as ſhall overcome the Ships attempt to ſail to Windward 30 Miles, or to its attempt to keep within a Circle of 30 Miles in Diameter. However,

N. B. If any prodigious Storms ſhould ſometimes drive it out of ſight of the Buoy, yet will not this be any very great or long Inconvenience: becauſe, aſſoon as the Storm is abated, they can immediately ſail into and along the known Parallel of the Buoy, and ſo recover their former Station near it. Again,

N. B. Since it now appears by direct Obſervations, as has been already

dy hinted, that there are few or no Places of the Ocean too deep for caſting Anchor, 'tis very probable there may be little or no occaſion for any other way of fixing theſe Buoys than that by Anchors; which is the ſure, plain, and moſt obvious Method for that Purpoſe.

N. B. Theſe Buoys may be placed in proper Stations as to Latitude, by the known Methods of obſerving the Latitude; and as to Longitude, by the Eclipſes of the Sun, or Moon, or of *Jupiter*'s Planets, or by the Moon's Appulſe to fixed Stars; or rather by an actual Menſuration of Diſtances on the Surface of the Sea by Trigonometry, juſt as Monſieur *Picard* and *Caſſini* meaſur'd the Length of a Degree of a great Circle on the Land; while the Lights to be thrown up from the Ships will afford the ſame Advantage that any elevated Mark does at Land, and while the vaſtly greater Length of a Baſis or meaſur'd Line

on the Shore; the vaſtly greater Diſtances of the Ships; and the much greater Evenneſs of the Surface of the Sea than of the Land, do give us hopes of more Exactneſs in this Way of Menſuration than in any other.

N. B. By the ſame Method, if done with ſufficient Accuracy, we may alſo hope to diſcover the Quantity of a Degree in all ſorts of great Circles, and perhaps more exactly than even Monſieur *Picard* or *Caſſini* have been able to do: becauſe we may hereby actually meaſure a much larger Portion of ſuch great Circles than they could; eſpecially if the Sound can alſo be heard at ſuch great Diſtances, and compar'd with the other Trigonometrical way of Menſuration. Which Advantage of this Method is in it ſelf very conſiderable. Nor is there any Reaſon why it may not be put in Practice at Land alſo, for the ſame Purpoſe; eſpecially on large Continents.

XVI.

XVI. If the Altitude of the Sun, at the beſt Advantage, can be taken within four Minutes of a Degree at Sea or Land; the time is thereby determined to about half a Minute: if to two Minutes of a Degree, the time is determin'd to about a quarter of a Minute, even in our Latitude; while nearer the Equator the like Limits determine the Time ſtill more exactly.

This the Aſtronomers well know: and any that obſerve in common Quadrants how an Hour, in the middle between Noon and either Morning or Evening, contains uſually about 7 or 8 Degrees of Altitude; while no leſs than 15 Degrees makes an Hour upon the Equator, will eaſily agree to this Propoſition.

XVII. The beſt time for the exact Diſcovery of the Hour at Sea, and of

of adjuſting all Watches or Movements to ſhew the ſame afterwards, is that of the riſing and ſetting of the Sun; that is, in caſe Allowance be made for the Horizontal Refraction of his Rays; but not otherwiſe.

For if the time while the whole Body of the Sun is riſing or ſetting, which may be very nicely obſerv'd at Sea, be added at Night to, and ſubſtracted in the Morning from, the Time that any Table of its riſing and ſetting, or a particular Trigonometrical Calculation, does determine; the Sum in the firſt, and Difference in the ſecond Caſe will give the true Time when the Sun's Center will appear to be in the very Horizon. And this becauſe the Sun's Horizontal Refraction is obſerv'd to be very nearly equal to his apparent Diameter.

N. B.

N. B. The exact time of the Sun's rising and setting, from Six a Clock, at all Declinations, and in all Latitudes, is found by the following easy Rule of Trigonometry.

As the Radius:
To the Tangent of the Latitude:
So is the Tangent of the Declination:
To the Sine of the Hour from Six.

For an Example. Let us compute for the Longest Day, in the Latitude of 51°. 30'.

Rad. 90°. Log. 10. 0000000.
Tang. Lat. 51. 30'. Log. 10. 0993948.
Declin. 23. 29. Log. 9. 6379563.
Sin. Log. 9. 7373511. = 33°. 6'. 24".
i. e. = 2h. 12'. 28". Q. E. I.

Note also that the Amplitude cannot be exactly taken, even at Sea, without the like Allowance for Refraction. And the Difference of Amplitude, when the first Edge of the Sun touches, and the last leaves the Hori-

Horizon, is to be added or ſubſtracted in this Caſe, to or from that when it appears to be half ſet; in order to obtain the Sun's true Amplitude: as well as we added or ſubſtracted the Difference of Time before, for the exact Adjuſtment of the true Moment of its riſing and ſetting.

The Solution of the Problem.

Let a Mortar or great Gun, with a Shell that will take Fire at its utmoſt Altitude, be diſcharg'd perpendicularly 6400 or 10000 Feet high above the Surface of the Sea, every Night exactly at 12 a-Clock, and in foggy Weather the next Hour after the Fog is clear'd up alſo, at all convenient Diſtances and Situations, and from known Places. This Diſcharge will, by the Diſtance and Point of the Compaſs of its Sound, nearly give the Longitude and Latitude to all Places or Ships within the hearing

ing thereof: And it will, by the ſame Diſtance and Azimuth of its Light or Fire, exactly give the ſame Longitude and Latitude to all Places or Ships within the Sight thereof; according to the foregoing Lemmata. Q. E. I.

For Example: Let us ſuppoſe a Ships Station to be fixed in a known Place, 30 Degrees more Weſtward than the Meridian of *London*; and that every Midnight its Mortar or Great Gun is diſcharged, as before; and that a Ship ſailing by at 54′. 40″. after Eleven, ſees the Fire or Light 30′. above the Horizon; *i. e.* by the foregoing Table for 6400 Feet Altitude and 40″. at 60 Minutes, or Geographical Miles diſtance. It was therefore 12 a Clock at the Hull, when it was only 11 h. 55′. at the Ship. So that the difference of Time is 5′. and the difference of Longitude upon the Equator 1°. 15′. and the Ships Longitude from the Meridian

of *London* is hereby known to be 31°. 15′. Weſtward.

Suppoſe alſo that the Weather be ſuch that only the Sound can be heard, and that it proves to be ſo weak as to be juſtly eſteem'd 65 meaſur'd Miles diſtant. This Diſtance anſwers to about 5′. of Time, for the Interval of the Propagation of the Sound: which therefore, if it be heard juſt at 12 a-Clock at the Ship, will imply that when the Exploſion was made, it was at the Ship only 55′. paſt 11, the ſame Moment that it was full 12 at the Hull; and that therefore the difference of Meridians is the ſame as before, *viz.* 5′. in Time, or 1°. 15′. upon the Equator, Weſtward.

Suppoſe farther, that the Light be ſeen at the ſame time that the Sound is heard; with no other than the ſmall difference of the ſlowneſs of the Sound, in compariſon of the inſtantaneous Motion of the Light; and

and that the difference of Time between the moſt elevated Appearance of the Light and the hearing of the Sound; (which may be eaſily and exactly obſerv'd by any tolerable Movement whatſoever, or by a Pendulum, that vibrates half Seconds:) be found to be 4'. 40". or, which is all one, that the intire difference of the Exploſion made, and of the Sound heard, be 5'. in Time. This difference will imply the diſtance of the Ship from the Exploſion to be 65 meaſur'd Miles. And if the Sound is heard at the Ship 54'. 40". after Eleven, the difference of Longitude upon the Equator will ſtill be 1°. 15'. and the real Longitude from *London* will be 31°. 15'. Weſtward, as before.

If the Azimuth of the Fire or Light be alſo obſerv'd, take with your Compaſſes from your Scale the true diſtance, 65 meaſur'd Miles, and ſet it from the place of the Hull, on the true Angle, in any

large Map or Sea-Chart. This will determine the very Point where the Ship is, both for Longitude and Latitude. The ſame thing may be done for the Sound, in caſe the Point of the Compaſs be obſerv'd alſo.

If the Latitude of the Ship be known, take the known diſtance, either by the means of the Light or Fire ſeen, or, if the Weather be too Foggy for that, of the Sound heard; and let it croſs the known parallel of Latitude in the Chart; and this will determine the Longitude. The like is to be done for the Latitude, were the Longitude firſt known. But that not being the uſual Caſe, it needs not be farther inſiſted on. Nor need we ſhew how all this may be done by Calculation alſo, ſince thoſe that underſtand any thing of Navigation cannot be to ſeek therein.

N. B. It is found by Experience, that the Light of the Moon is too faint to give much Diſturbance to the

the Light or Fire here made uſe of. Otherwiſe an Exploſion ought alſo to be made for ſeveral Nights before the Full, the next Hour after the Moon is ſet; and for ſeveral Nights after the Full, the next Hour before the Moon is riſen; beſides the ordinary ones at Midnight.

N. B. Since the Wind is very ſeldom conſiderable in foggy Weather, the Sound will be very ſeldom hinder'd by the Wind, when there is the greateſt occaſion for it; that is, when the Air is too thick to permit the Light to be ſeen; which is a great Convenience in that Caſe: tho' it muſt be own'd, that foggy Weather does it ſelf damp Sounds very conſiderably.

N. B. If what is ſaid by ſome well acquainted with Navigation be true, *viz.* that Fogs are much rarer in the main Ocean than near the Shores, our Method by the Ball of Light, nay, and by the Sound alſo, will

will be there leſs interrupted than at and near the Coaſts; to the great Advantage of the moſt difficult Part of our intire Diſcovery.

N. B. If the Publick be willing to ſave part of the Charges of this intire Method, and be contented with the Light, without any very great Sound; a moderate Mortar, and no great Quantity of Gun-Powder will ſuffice. But if it be thought fit to have the Sound as well as the Light, in their utmoſt Perfection, the largeſt Cannon-Royal, and its intire Charge of Powder, will be but neceſſary. Or it may be ſo contriv'd, that there be every where both a moderate Mortar for clear, and the largeſt Cannon-Royal for foggy Weather.

N. B. If there be any danger of miſtaking one Exploſion for another in any Caſe, the Light may be diverſify'd; and Balls of Fire whiter, redder, and bluer made uſe of, in

in a Row, according to one conſtant Order. Or, as my Lord *Pembroke* very well propos'd, the firſt Exploſion may be ſingle, the ſecond in order double, at a certain Interval of Time; the third double at twice that Interval; the fourth double at thrice that Interval; and ſo on. By either of which Proviſions this Ambiguity, if it any where ſhould be ſuſpected, may be intirely prevented. Tho' indeed at that great Diſtance of about 600 Miles, which we propoſe the Exploſions at Sea to be from one another, any ſuch Miſtake is *there* next to impoſſible.

N. B. In caſe ſome parts of the Ocean prove ſo very rough and ſtormy that no Ships care to have their Stations in them, the way to recover the Longitude, which may be by this means interrupted, is rightly propoſed by Sir *Iſaac Newton* himſelf, in his Paper deliver'd in to the Committe of the Houſe of Commons,

mons, *viz.* to ſail obliquely from the laſt Buoy and Stationary Ship into the Parallel of the next, and ſo along the ſame; till upon approaching to to them the Longitude be anew recover'd, and the Voyage be continued as before. Nor is this Interruption of any conſequence; becauſe it cannot happen but in Places where there is no Danger of this Nature; and where Seamen are under no great Concern for the knowledge of the Longitude.

OBSER-

OBSERVATIONS.

(1.) IF in all proper Roads of Ships such a Mortar, or Great Gun be plac'd and discharg'd, exactly every Midnight, whether on Shoars, or Islands, or in the Stationary Ships, at the Distances of about 600 Geographical Miles or 10 Degrees, All other Ships that sail within any tolerable Distance may commonly every Week or Ten Days thereby correct their Reckoning, and know their Longitude, as well as Latitude, even when the Heavens are not clear enough to make Celestial Observations for either.

(2.) The Ordinary Watches, Movements, or Log-Lines in Ships, when thus Corrected and Adjusted, once

in a Week or Ten Days, will well enough ſhew the Longitude during every one of thoſe ſhort Diſtances between the Stationary Ships; and ſo will render the Knowledge thereof ſtill more univerſal.

(3.) The exacter therefore any Movements that may be uſed at Sea can be regulated, and adjuſted to an even Motion, the more beneficial will they be in this Method. So that tho' any ſuch Movements ſhould not ſucceed ſo far, as themſelves to diſcover the Longitude alone, of which there is indeed ſmall Hopes; yet if they be at all improv'd they will give Aſſiſtance in this or any like Method for its Diſcovery; and will therefore juſtly deſerve from the Publick both Approbation and Encouragement.

(4.) If one ſuch Row of Stationary Ships be any where found too de-

defective, a double Row may there be laid, Pair by Pair, in the ſame [or equidiſtant] Meridians; with proper Diſtinctions in the Sounds, or the Light, to prevent miſtaking one Row for the other. Nor will there, in this Caſe, be room for almoſt any Uncertainty, ſince even in Cloudy Weather, as much as the Wind carries away the Sound of any one, ſo much will it uſually bring the Sound of another.

(5.) If it be any where neceſſary, Maſts may be Erected upon Hollow Empty Veſſels, with White Spheres at their Tops; and theſe Veſſels may be fix'd in proper Places, at equal Diſtances between the Stationary Ships, for the more ſure guiding the other Ships in Places of Danger. And ſince from the Top of any Maſt that is 88 Feet High, the Top of another as high may be diſcovered at the Diſtance of 20 Miles,

there will hardly be occaſion for more of theſe Veſſels any where than one every 120 Miles: Nor will theſe Maſts and Veſſels be any Annual Charges at all.

(6.) Beſides the Mortars or great Guns, and their ſolemn Exploſions; In proper Places, at ſeveral Havens, where there is any Danger at the Entrance of Ships, as well as at other convenient Promontories jetting out into the Sea, a Rocket may be thrown up from the Top of a Neighbouring Steeple, or Hill, or the like moſt elevated Place, every Midnight, or Watch, or Hour, for the Seamens better Direction and Security.

(7.) Signals of all Sorts may be given by this Method, by mutual Agreement. As ſuppoſe in Storms we would know which way, and how ſtrong the Wind is at the near-

eſt

eſt Exploſion, &c. Other Ships may thus give Signals of Diſtreſs to the Stationary ones, or to one another. The News of great Events may be alſo this way carried very ſoon over the Sea; eſpecially, if any Ships were plac'd within Sight and Hearing of each others Signals, as a Fleet may ſail in Times of Peace, &c. In ſhort, no one knows how far this Method of Communication by theſe Kinds of Signals may be improv'd; and how great a Convenience may hence ariſe to the ſeveral Parts of the Globe; eſpecially in the Way of Trade and Commerce; and even for the Propagation of Knowledge both Divine and Human throughout the World.

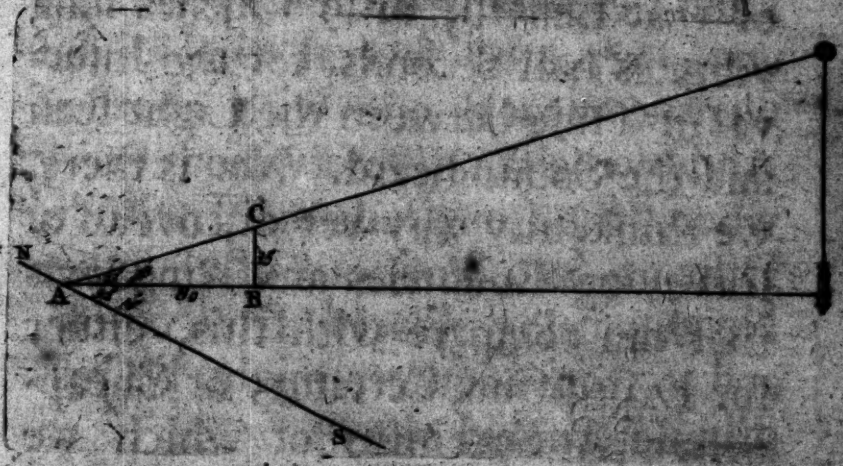
(8.) If in any clear and calm Night a ſufficient Number of ſuch Exploſions were made at proper Diſtances in any Country, and convey'd in order from one to another;

ſo

ſo that the Second Mortar or Gun were fired when the Light of the Firſt was ſeen, or otherwiſe; with the Obſervation of the exact apparent Times when they were made, when the Light was ſeen, what Angle, or how long that Light was above the Horizon, and what Azimuth it had; both the Longitude and Latitude, as well as the Diſtance and Poſition of all theſe Places, might by this means be readily determin'd at Land; eſpecially if the Experiments were repeated ſeveral times, and were compar'd one with another. And by the ſame Obſervations every where, the Longitude and Latitude, Diſtance and Poſition, of all other Neighbouring Places from thoſe, and ſo from another, might be readily determin'd alſo:

N. B. This Method of Survey is no hard Thing in Practice, even to thoſe that know little of the Mathematicks:

maticks: For any Right Angle, ſet by a Plummet or Level, with Two Pins or Points, for the Eye and for the Object, does by the Proportion of its Sides give the Angle above the Horizon; by the Angle its Horizontal Side makes with the Meridian, it gives the Azimuth; and by the Interval of Time between the Light and Sound, it gives the Diſtance of every Place from that of Exploſion, according to the Figure following.



Where A B repreſents the Horizontal Side of the Norma or Square, and B C the Perpendicular Side; whoſe

whose Proportion once given, as suppose 80 to 35, the Discovery of the Angle of Elevation C A B is most easy, as here 23°. 38'. Where also N S. represents the Meridian Line lying from North to South; and the Angle S A B, suppose of 32 Degrees, 15 Minutes, represents the Azimuth, Eastward. We need not add that a Plummet of 39.2 Inches vibrates whole Seconds, as in long Pendulums, and of a quarter of that Length, or 9.8 Inches long vibrates half Seconds, for the Interval of Time between the Light seen and the Sound heard. Nor is there, we think, any way yet discover'd of surveying Countries and Kingdoms that can compare with this, either for Expedition, Certainty or Cheapness. A Specimen of which we hope soon to give the World in an Actual Survey of *Great-Britain* and *Ireland*, and their Coasts hereby; if the Publick please to give us

En-

Encouragement and Aſſiſtance therein.

N. B. The Obſervation of the Altitude is at Land leſs exact than at Sea, becauſe of the Inequality of Hills and Valleys, and the conſequent Uncertainty how high any Mortar or Gun is above the level Surface of the Sea. However, it is plain that we don't want that Method in this Land Survey; becauſe we can place our Mortars or Guns ſo nigh, and take ſuch clear and calm Weather for our Obſervations, that the Sound will more than ſupply that Defect. Which Method of knowing Diſtances, by the Interval of the Sound, is now, from the nice Experiments made by the *Italians*, the *French*, and by our Famous Mr. *Flamſteed* and the ſtill more authentick ones of the Accurate Mr. *Derham*, become the moſt exact of all others for this Purpoſe. In order

to which Design, I do here propose a Table for the Ease of all that make use of the same Method. See Mr. *Derham*'s full Account of this Matter, *Transact. Philosoph.* N°. 313.

A Table of the Velocity of Sounds in still Weather at 1142 Feet to one Second of Time.

Statute Miles.	" Interval of the Sound.	Statute Miles.	" Interval of the Sound.
1	4 1/8	19	87 7/8
2	9 1/4	20	92 1/2
3	13 7/8	21	97 1/8
4	18 1/2	22	101 3/4
5	23 1/8	23	106 3/8
6	27 3/4	24	111
7	32 3/8	25	115 5/8
8	37	26	120 1/4
9	41 5/8	27	124 7/8
10	46 1/4	28	129 1/2
11	50 7/8	29	134 1/8
12	55 1/2	30	138 3/4
13	60 1/8	31	143 3/8
14	64 3/4	32	148
15	69 3/8	33	152 5/8
16	74	34	157 1/4
17	78 1/2	35	161 7/8
18	83 1/4	36	166 1/2

Statute

Statute Miles.	Interval of " the Sound.	Statute Miles.	Interval of " the Sound.
37	171 1/8	44	203 5/8
38	175 3/4	45	208 1/8
39	180 3/8	46	212 3/4
40	185	47	217 1/8
41	189 5/8	48	222
42	194 1/4	49	226 1/8
43	198 7/8	50	231 1/4

N. B. Double or triple the Seconds belongs to double or triple the Number of Miles. So that this Table will ſerve for any Diſtance and Time whatſoever.

N. B. Mr. *Derham*, in his Account of Sounds, did not only ſtate this their Velocity with great Exactneſs, which is the principal thing in ſuch a Survey; but did propoſe this very Uſe of it alſo, as to ſmall Diſtances, ſo nearly to the preſent Obſervation, that he is to be allow'd to have gone a great way towards this Branch or Uſe of our Diſcovery.

N. B. Yet may it be proper, before any new Survey is made by this Method, to have this Velocity of Sounds try'd at larger Diſtances than that of twelve or thirteen Miles, which was the fartheſt that Mr. *Derham* had Opportunity for. I mean at 30, 40, or 50 Miles diſtance, where the Sound can be heard ſo far; and this in ſome plain Country, and where the Diſtance can be exactly meaſur'd, in a ſtrait Line, at the ſame Time. Which Tryal, if once done with ſufficient Accuracy, will ſettle this Point for ever. The Rectilinear Canal call'd *New Bedford River* in the Iſle of *Ely*, and the famous and ſtrait *Roman* Road call'd *Watling-Street*, eſpecially as it paſſes very nearly in a direct Line through the plain Country of *Staffordſhire*, ſeem very fit places for this Experiment; and accordingly in the Survey we are now going upon

upon, we have pitch'd upon them for the ſame Purpoſe.

(9) The way of caſting a Shell to any Height is very eaſy: for the ſame Force or Charge of Gun-Powder that will caſt any Shell twice as far for it utmoſt Random, at the Elevation of 45 Degrees, will certainly caſt the ſame Shell perpendicularly upward as high as is requir'd; as we have already obſerv'd. And ſince the Time of any ſuch entire perpendicular Projection, or Aſcent and Deſcent together, may be known from a former Table; We have another ſure Way of Adjuſting the ſame Projection to that Height; *viz.* by obſerving what Quantity of Powder will caſt the Shell high enough to ſtay a certain Interval in the Air, before it falls to the Ground; only the Reſiſtance and Retardation by the Air is to be diſtinctly allow'd for.

(10.)

(10.) This Method of firing Powder, or other combuſtible Matter, at, or very near the utmoſt Height, may be well enough put in practice, even tho' ſome conſiderable Error ſhould be committed in the adjuſting the Fuſee to give Fire at ſuch a Time. Since the Miſtake of even a Fifth Part in Time, in that Caſe, would produce but an Error of the 25th Part of the whole Altitude: and the Miſtake of a Tenth Part in Time, would occaſion an Alteration of no more than the Hundredth Part thereof. This is evident, becauſe this Time belongs to the higheſt Part of the Projectils Motion, which is the ſloweſt: And becauſe the Lines deſcrib'd by all Aſcending and Deſcending Bodies are ſtill in a Duplicate Proportion of the Times of ſuch their Aſcent and Deſcent.

(11.)

(11.) If one or more Rows of ſuch Stationary Ships were laid in the ſame or Equidiſtant Meridians, Southward or otherways, Ships might with greater Safety than formerly go to diſcover thoſe Parts of the Globe which are hitherto undiſcover'd. Nor can we at preſent gueſs what Advantages may thereby accrue to the Parts of the World already diſcovered.

(12.) If Foggy Weather be not ſufficiently provided for by what has been already mention'd, the Stationary Ships may be laid cloſer, at leaſt near the Shore; that ſo the occaſional Defect of one, or ſometimes two Exploſions, *i.e* of one intire Stationary Ship's Aſſiſtance, may not produce any conſiderable Error in ſailing. Tho' it muſt be remembred, that this Foggy Weather hinders the Obſervation of the

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Latitude; and that Clouds alſo which hinder us not, do yet hinder the ſame: which Latitude yet is alway eſteem'd to be diſcover'd notwithſtanding: and that all the Harm which need enſue thereby is only the delay of a few Days in a Voyage, till the Air clears up: without the incurring of any Danger in the mean time.

(13.) Every one of theſe Stationary Ships may be Places of Obſervation as to the Variation of the Needle, to the Currents, to the Soil, the Fowls, the Fiſhes, and other *Phænomena* of the ſeveral Places where they are fixed; and an excellent Means of keeping up a mutual Correſpondence between the ſeveral Parts of the Globe, for all uſeful Purpoſes whatſoever.

(14.) Theſe Stationary Ships will be an excellent Nurſery for skilful Sailors;

Sailors; and will uſe them to the greateſt Dexterity in handling and working of Ships to the beſt Advantage.

(15.) As this Method ought to be put in Practice at Sea by the Conſent of all Trading Nations; ſo ought every one of the Stationary Ships employ'd therein to have a legal Protection from them all: And it ought to be a great Crime with every one of them, if any other Ships either injure them, or endeavour to imitate their Exploſions, for the Amuſement and Deception of any.

(16.) Since the Charges of the Powder for each Mortar will be very ſmall; ſince the Shells may be generally the ſame, and their Contents come to no great Price neither; ſince the Perſons employ'd in the Stationary Ships may be in part taken out of ſuch Places where they

are maintain'd at the Publick Charge already; and ſo will require only ſome Additional Rewards, or Future Privileges for ſuch their Service; ſince the Number of ſuch Stationary Ships need be but ſmall, ſcarcely more than Fifteen, or Twenty at the moſt; and ſince the Land Exploſions, which will be much the moſt numerous, will be withal much the cheapeſt; It will appear upon the Whole, that the Annual or Conſtant Expences of this Method will be comparatively very ſmall and inconſiderable; eſpecially if they are, as they ought to be, equally diſtributed among the ſeveral Trading Nations of the World.

The

The Advantages of this Method.

(1.) THIS Method requires no Depth of Aſtronomy, no Nicety in Inſtruments, and but ſeldom any Celeſtial Obſervations at all, either as to the Latitude, or the Hour at the Ship; and ſo is to even the common Sailors the *moſt Practicable*.

(2.) It does generally determine the very Place of the Ship, both as to *Longitude* and *Latitude* at once, and ſo is the *moſt Compendious*.

(3.) It does generally determine the very Place to a few Miles, at the fartheſt; and ſo is the *moſt Accurate*.

(4.) It ſometimes affords Help even in Cloudy and Foggy Weather, when no Celeſtial Obſervations can be made, and the *Latitude* it ſelf cannot be otherwiſe found, and ſo is the *moſt General*.

(5.) It will frequently afford a double Obſervation Two ſucceſſive Nights, from the ſame Stationary

Ship to the ſame ſailing Ship, and ſo is the *moſt Secure.*

(6.) It will frequently afford a double way of Obſervation at the ſame time, by the Eye and by the Ear, which will confirm or correct one another; and ſo is the *moſt Certain.*

(7.) The more inaccurate Branch, by the Sound, is not only more univerſal than the other; but is alſo much more exact than any Method formerly diſcover'd: So that in that Caſe this Way is certainly the *very Beſt.*

(8.) It is the moſt undoubted and exact near the Shores, where there is the greateſt Want and Danger: And if it ſhould at all be deficient, it is in the wide Ocean, or there only where there is no ſuch Danger, and hardly any Occaſion for knowing the Longitude, as has been ſhew'd already. So that on all Accounts it is plainly the *moſt Uſeful* and *Advantageous.*

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APPENDIX.

N. B. IT being of great Advantage, both in our preſent Survey of this Kingdom, and upon many other Occaſions, to know the true Altitude and Diſtance from the North of the Pole-Star at all times: I ſhall here add Tables to find the ſame to every half Hour of its diſtance from the Meridian, for the Latitude of 53°. which is nearly that of the middle of *England* and *Ireland*; and they will well enough ſerve for both Kingdoms, and for all other Countries that lie in the ſame Parallels with them.

Hours.		Diff. Altitude above the Pole.		Diſtance from the North.	
		°	′	°	′
XII	XII	2	13 ½	0	0
½	½	2	12 ½	0	30 ½
XI	I	2	8 ½	1	0 ½
½	½	2	2 ½	1	29 ½
X	II	1	54 ½	1	56
½	½	1	44 ½	2	20 ½
IX	III	1	32 ½	2	42 ½
½	½	1	18 ½	3	0
VIII	IV	1	3 ½	3	16 ½
½	½	0	48	3	28 ½
VII	V	0	31 ½	3	36 ½
½	½	0	14	3	45 ½

Hours.		Diff. Altitude below the Pole.		Diff. from the North.	
		°	′	°	′
VI	VI	0	3 1/3	3	41 1/3
1/2	1/2	0	20 2/10	3	38
V	VII	0	38	3	31
1/2	1/2	0	53 1/4	3	20 1/2
IV	VIII	1	9 1/2	3	6 1/4
1/2	1/2	1	23 1/3	2	50 1/3
III	IX	1	36	2	31
1/2	1/2	1	47	2	9 1/2
II	X	1	56 1/3	1	46
1/2	1/2	2	3 2/3	1	21
I	XI	2	9	0	54 1/3
1/2	1/2	2	12 1/4	0	27 1/2
XII	XII	2	13 1/3	0	0

N. B. If we always deduct the right Aſcenſion of the Sun from the right Aſcenſion of the Pole Star, which is now 0°. 9′. 15′. the Remainder will correſpond to the Time of the Pole Stars coming to the Meridian above the Pole: and 12 Hours before or after will be the Time of its coming to the ſame Meridian under the Pole. Thus, becauſe 11°. in *Aries* correſponds to 9°. 15′. of right Aſcenſion; when the Sun is there, which is *March* 20th, the Pole Star comes to the upper Meridian at Noon.

And

And becauſe 191°. of the Ecliptick, where the Sun is *Sept.* 22d, has 189°. 15'. right Aſcenſion, the Pole Star comes to the ſame Meridian at Midnight; and in both Caſes its Hours from that Meridian agree with the ordinary Reckoning of Hours with us. At other times it comes ſooner than the Sun about 4'. every Day, or an Hour in about 15 Days. Thus *April* 22d this Year, the Day of the great Solar Eclipſe, the Sun's right Aſcenſion is 40°. 15'. which deducted from 9°. 15. or 189°. 15'. the Remainder is 149°. 0'. This ſhews that the Pole Star comes to the upper part of the Meridian at 9h. 56'. before Noon; which is nearly 4'. for a Day, or an Hour for 15 Days, along the Ecliptick. And ſo in all other Caſes whatſoever.

N. B. It is farther humbly propos'd to the Learned, Whether it may not be proper for all Nations, upon this Occaſion, to agree upon one

first Meridian, or beginning of *Longitude*, for the common Benefit of *Geography*? And whether it may not be proper, in that Caſe, to fix it to the *Pike of Tenariff*, as the moſt noted Place already; and as the Place whence the Higheſt and moſt generally uſeful Exploſion may, in this Method, be made every Midnight continually, for the Diſcovery of the *Longitude* it ſelf?
